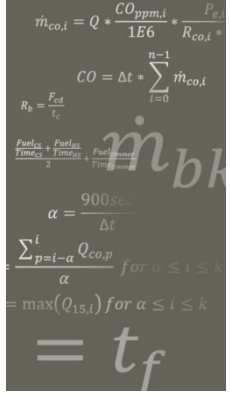

Microgrid Questions

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ENGINES & ENERGY CONVERSION LAB

Colorado State University

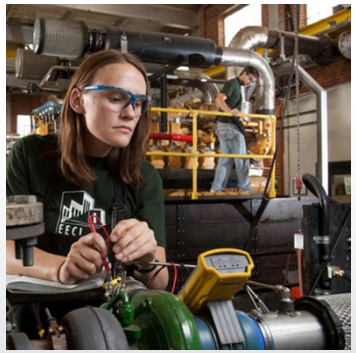
Renewable and Distributed Power Systems

Household Energy & Village Power

Engine Efficiency and Emissions

Biomass and Biofuels

Questions for Planning & Economics



Questions: Is deterministic analysis sufficient for μGrid planning and design?

1. Does deterministic analysis capture the value in μGrids?
2. Do deterministic assumption sets exist?
3. How does the analyst search for non-intuitive worst case conditions?
4. How to perform cascade failure analysis in large state spaces?
5. What is the impact of coupling at longer & more diverse time scales?

µGrid Value:

- Integrating high(er) penetration renewables
- Aggregating smaller DG sources
- Improving power quality
- Providing emergency power
- …

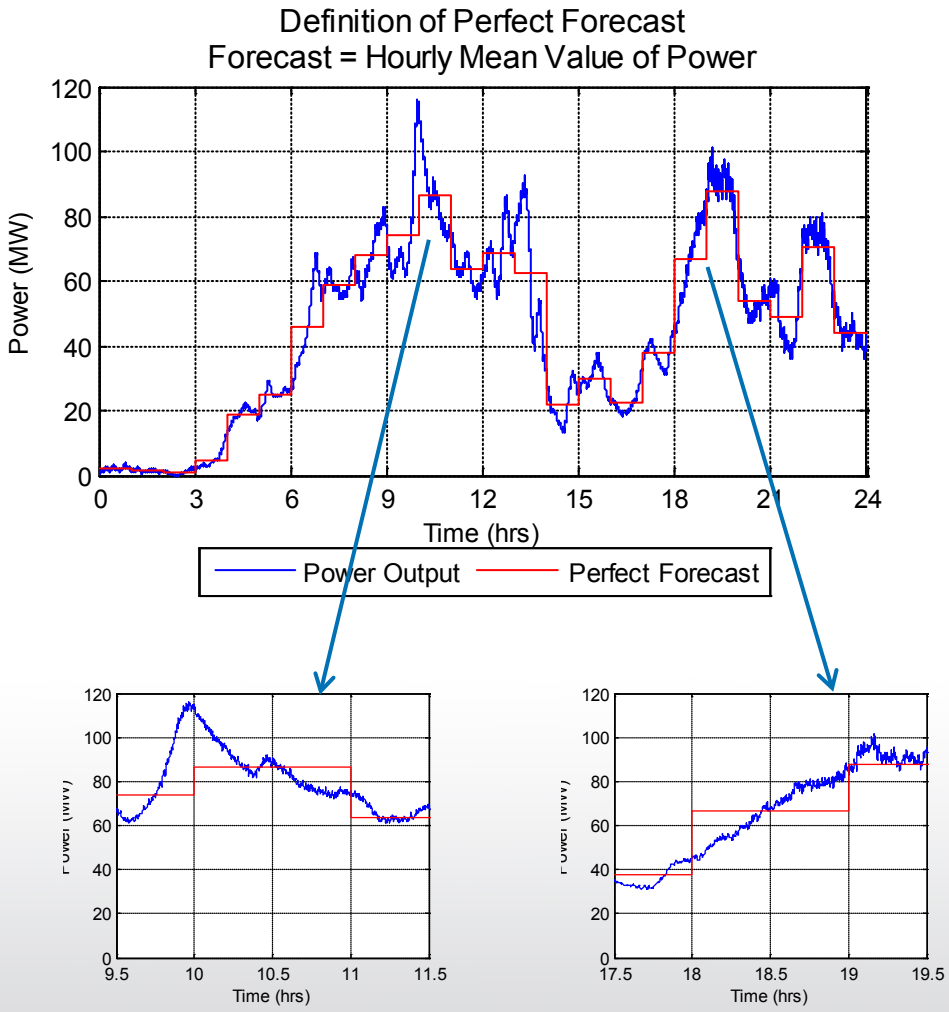
Do current analysis techniques correctly capture value of µGrids ?

Example 1: Stochastic Planning & Value

Irreconcilable Differences?

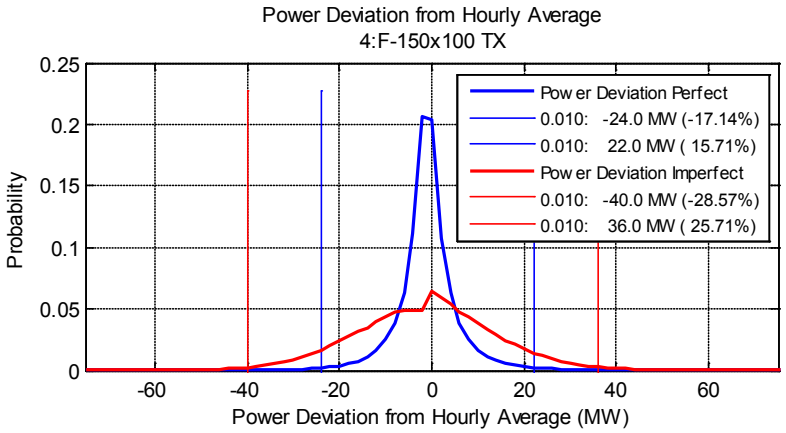
	Mr. Old Grid	Mr. New Grid
		
	"Give me a few big things I can control directly"	"Give me a thousand small things I understand stochastically"
Viewpoint:	Deterministic	Stochastic
Practice:	Stochastic	Stochastic

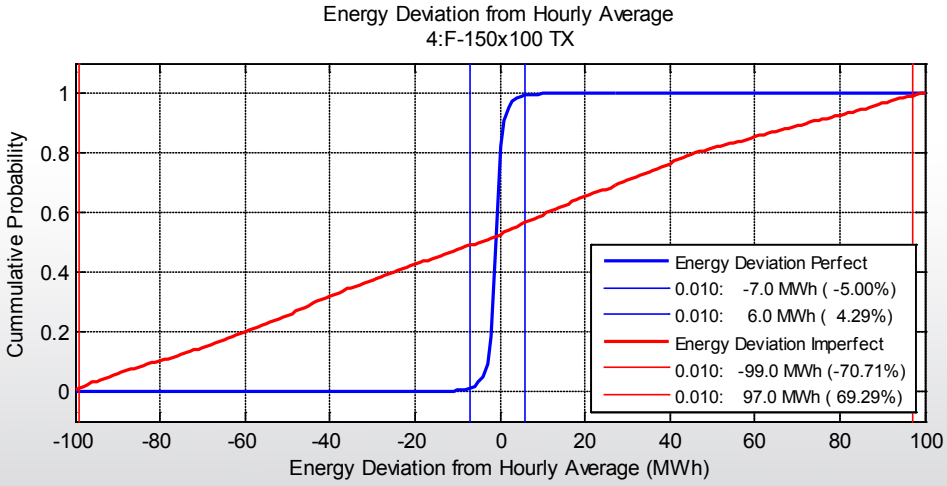
Renewable Variability



Forecast Accuracy

Power

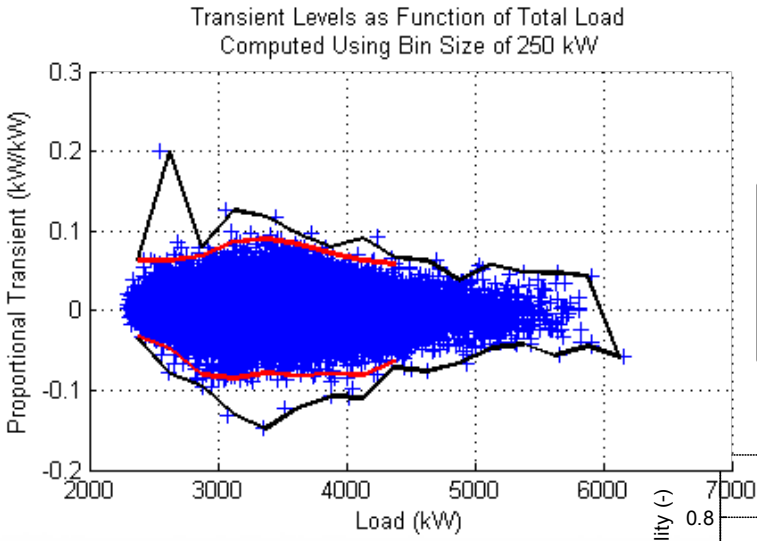


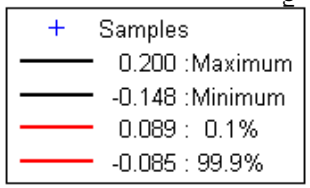


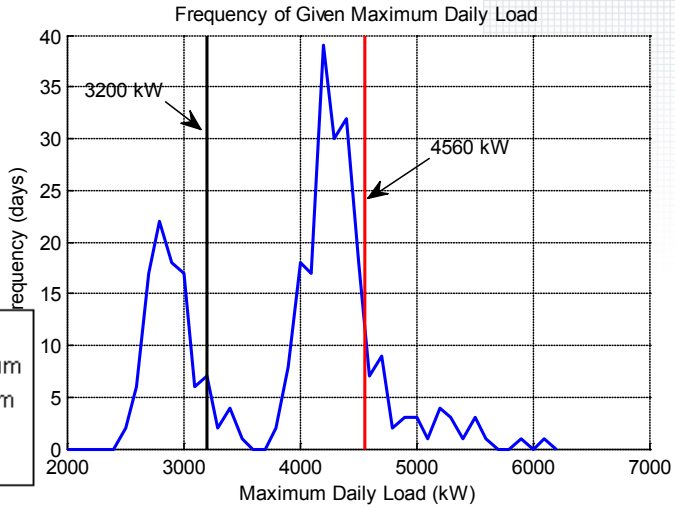
Energy

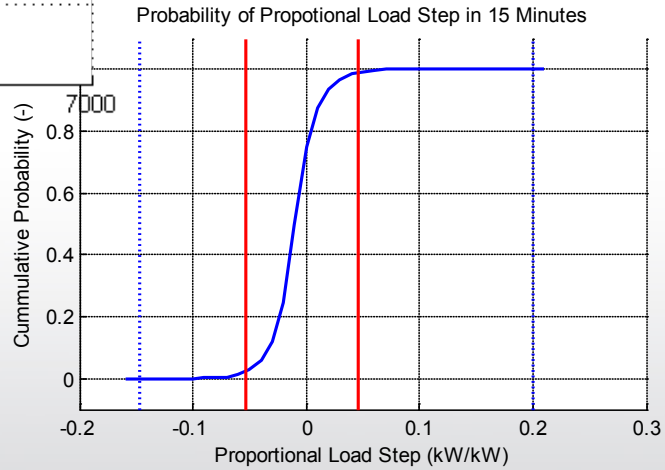
- Statistics calculated at 1 Hz, one year at a time, one trial only
- Forecasts are hourly total production forecasts
- Imperfect forecast: σ = 10% of rated power
- Threshold set to 1% & 99%

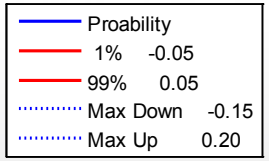
Thinking of Loads ...



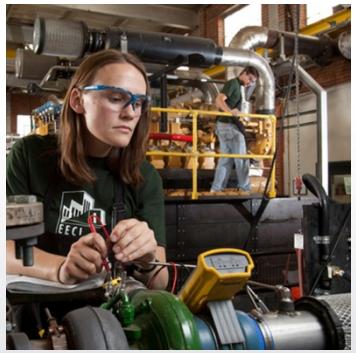








Questions for Island Systems

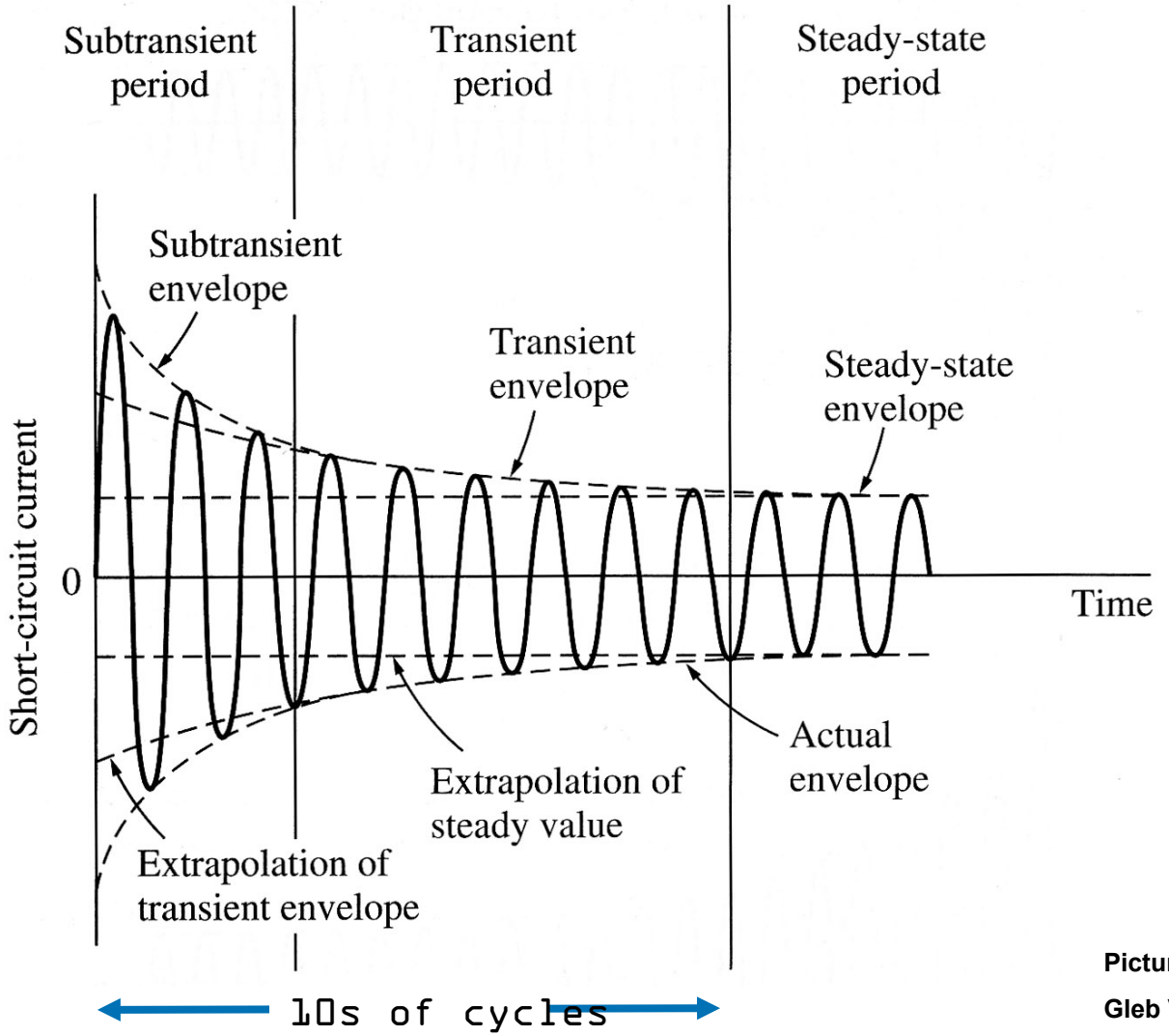


Questions for Island Systems:

1. How well do classic power system modeling approaches handle island system behaviors?
2. Do classic tools make incorrect assumptions for island systems?
3. Are machines and loads modeled correctly for island systems?
4. Do coupled power and communications systems have a material impact on operations?

Example 1: Transient versus Disturbance

Classic, Symmetrical Fault Transient



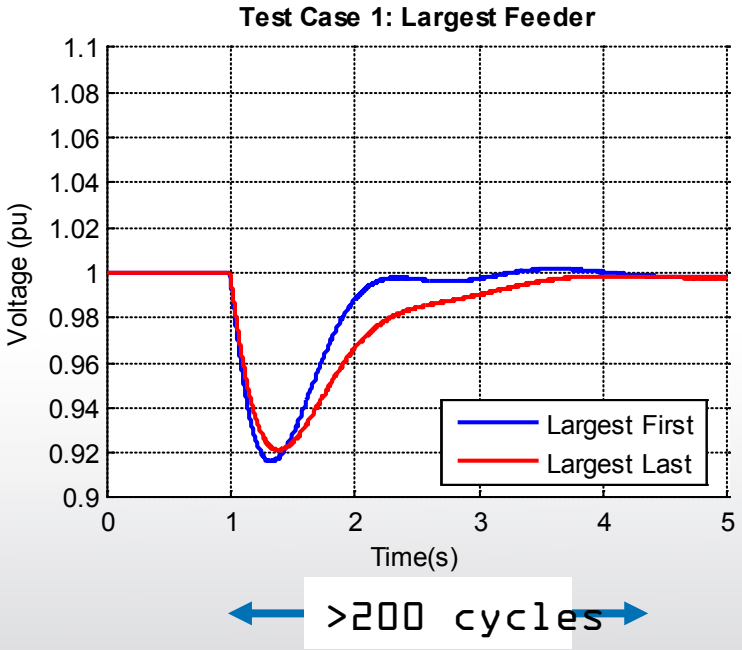
Picture from:

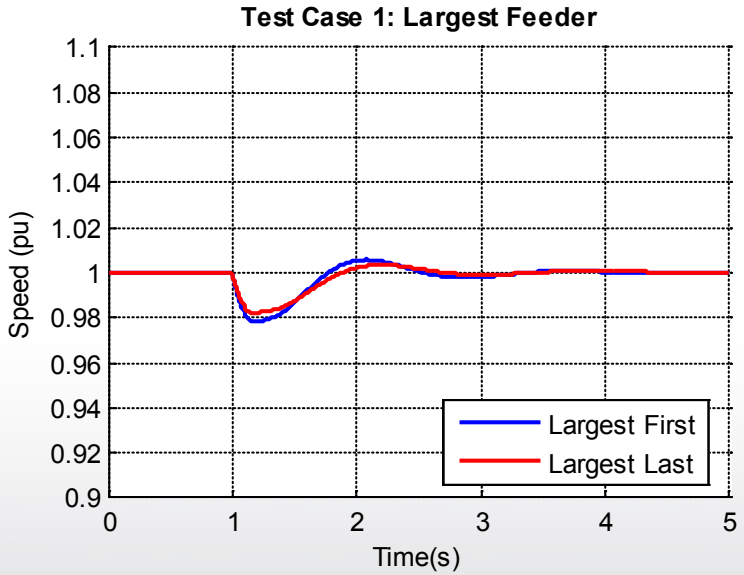
Gleb V. Tcheslavski

Lamar University

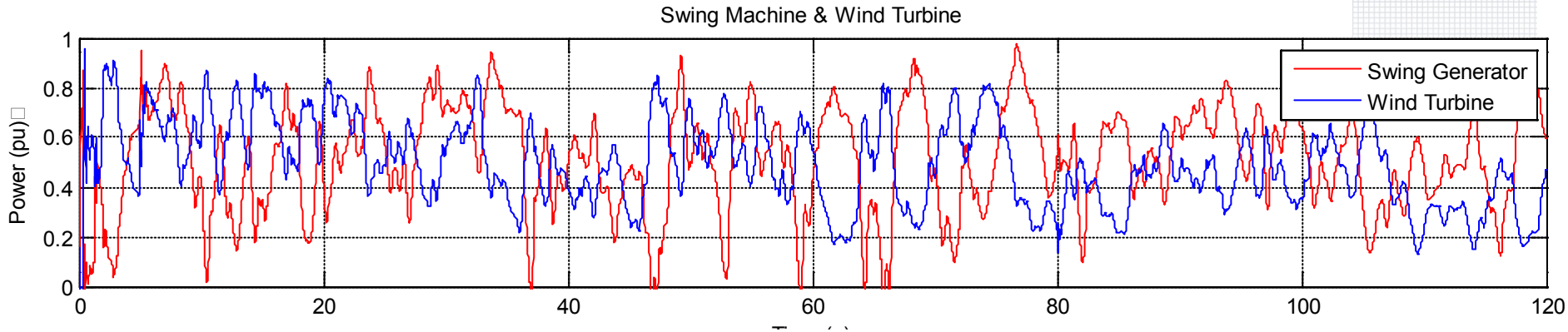
Similar Question … Islanded System

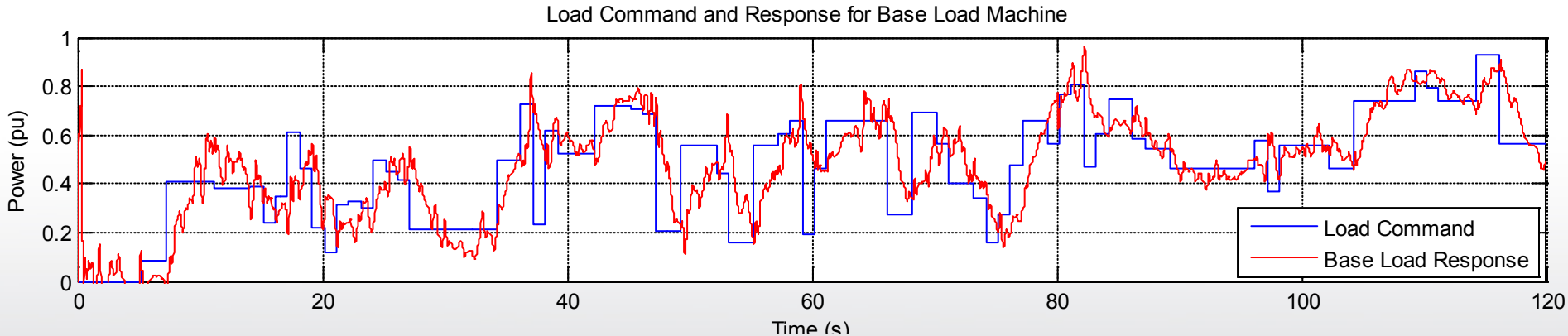
- 6 MW μGrid Powered by 3 Ganged Diesels
- Response to Added 2.2 MW of Load





Must also Consider Supervisory Control Timeframes





Contrast:

- Classic Power Sys.
  - Load Flow
  - Fault studies
  - Protection coordination
- Island Systems
  - Load flow
  - Fault studies
  - Protection coordination
  - Disturbance response
  - Supervisory control behavior
  - Communication latency studies

Steady State

Transients
10s cycles

Control & Communication
100s of cycles

Infinite Bus

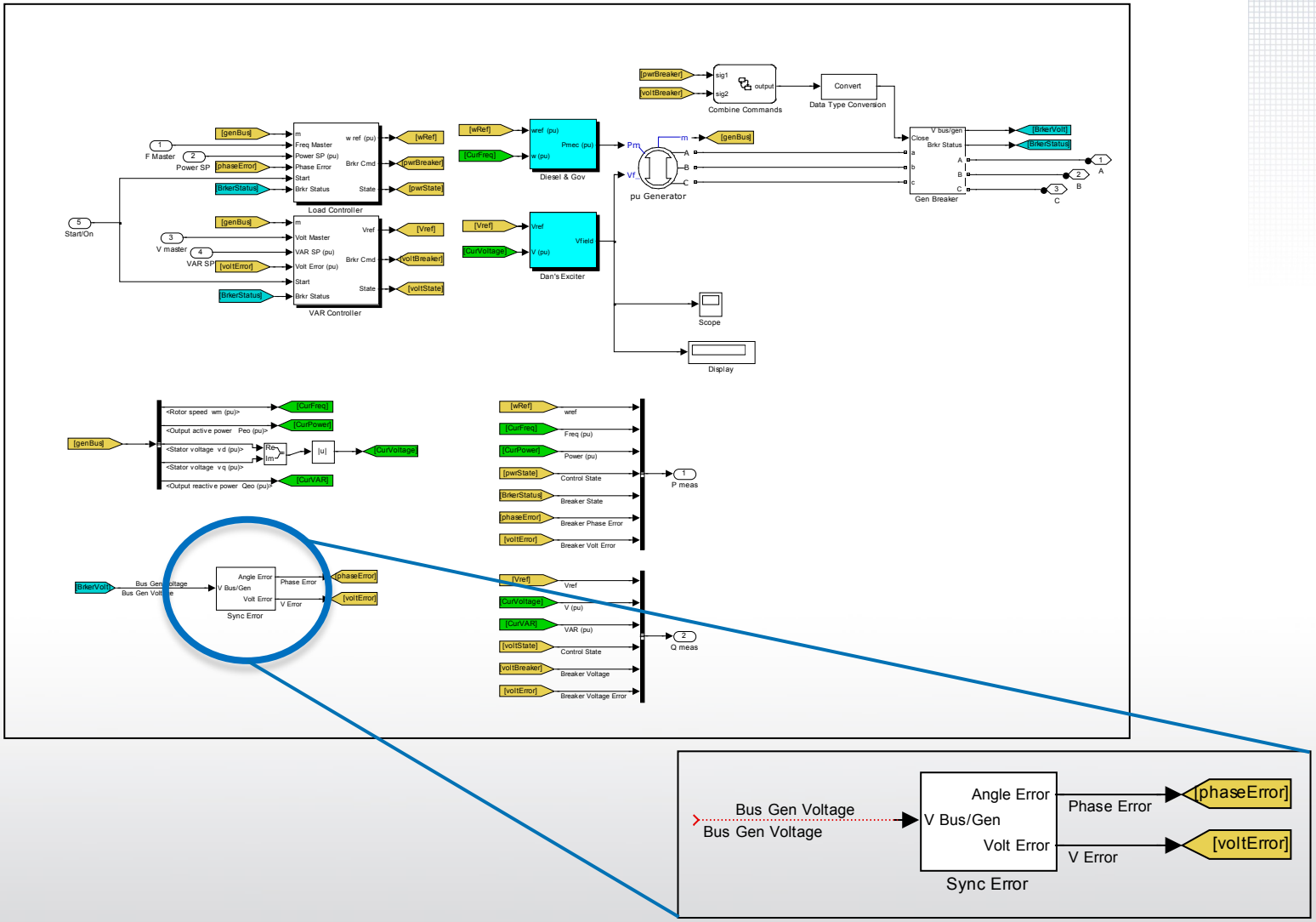
Finite Bus

Current µGrid simulation research:

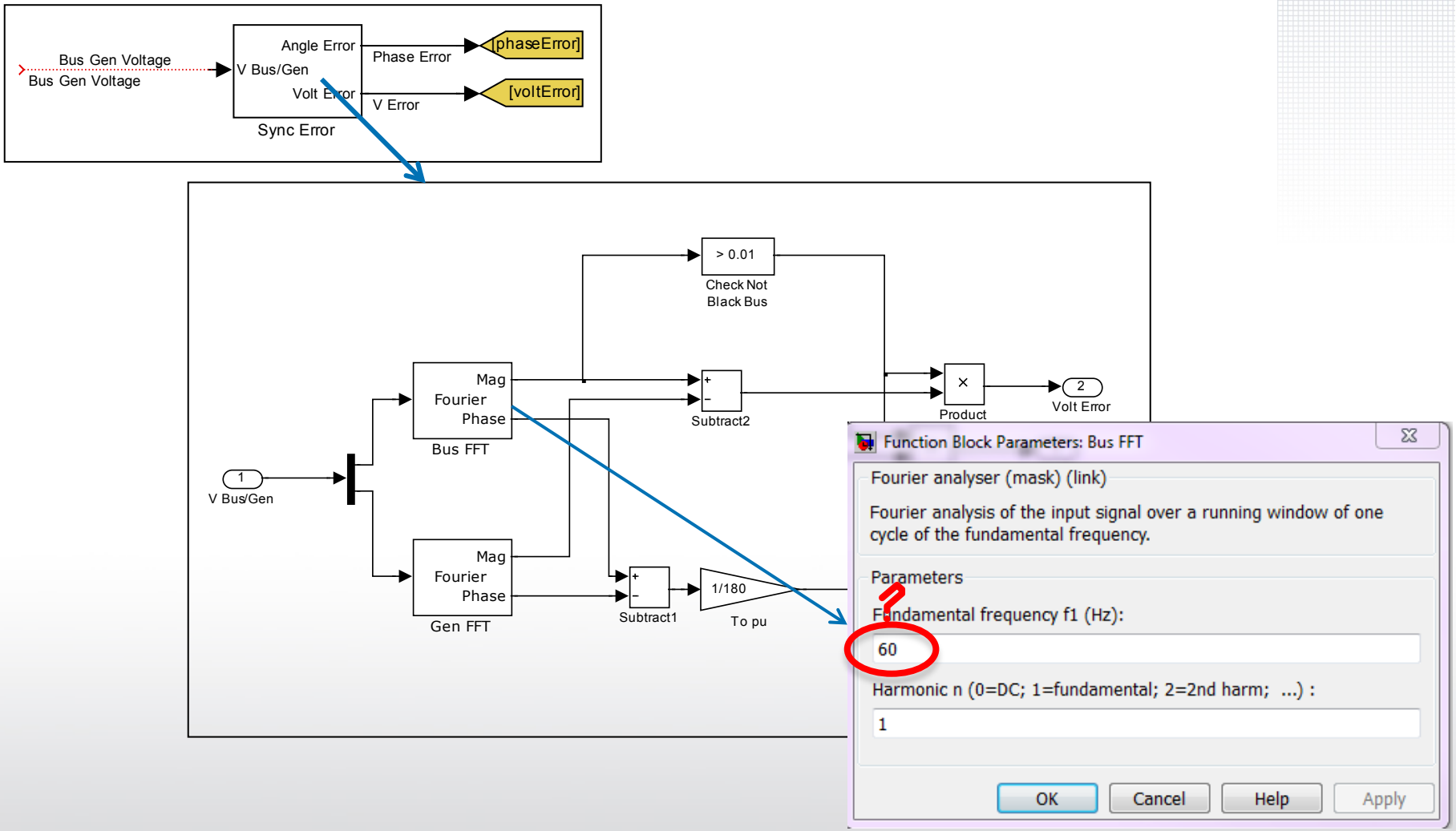
- Detailed Models in Longer Events
  - Transients → Disturbances → Unit dispatch
- Coupling between Distant Events
  - Storage integration – seconds to days
- Coupling between Disparate Systems
  - Power Systems → Controls → Communication Pathways → Congestion → Latency → Controls → Power System

Example 2: The Fixed-Frequency Assumption

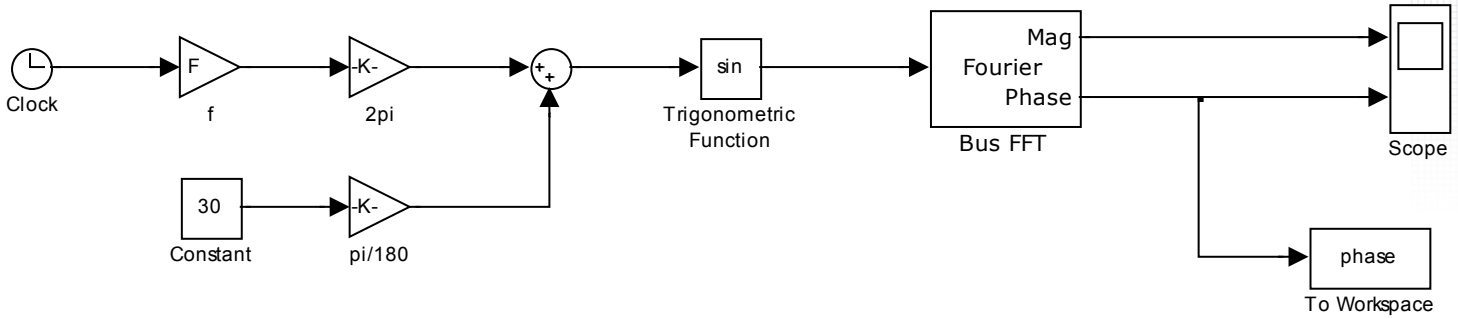
An Annoying Little Example: Fixed-Frequency Trap



A Little Deeper

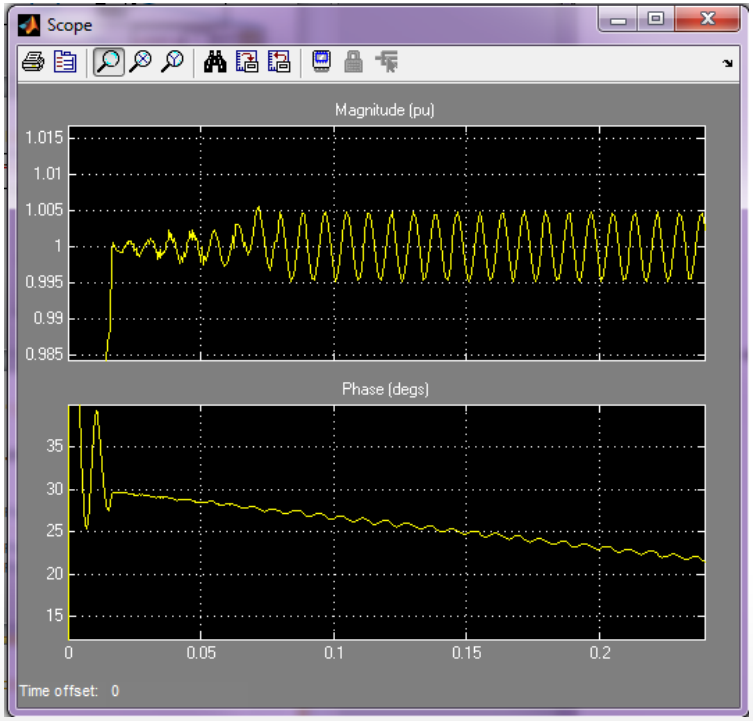


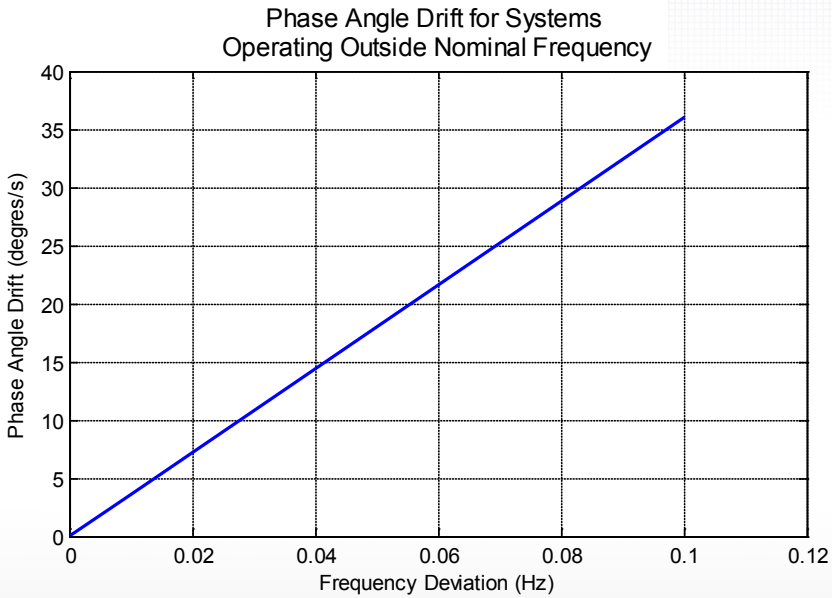
A “Can’t Get Any Simpler Than This” Test



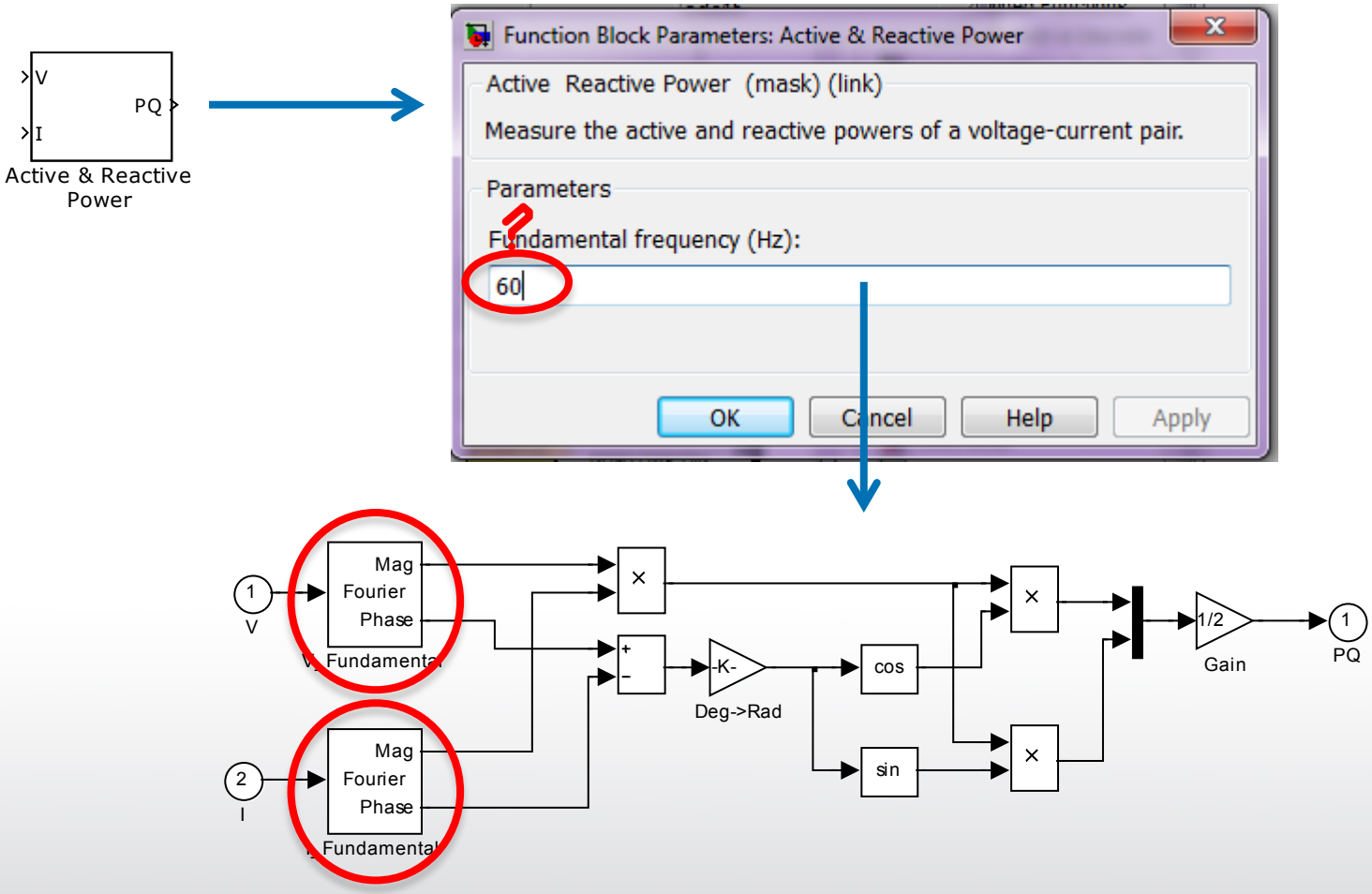
- Frequency = 59.9 Hz
  - … 0.17% Frequency Deviation
- Phase Angle: Constant
- Plot Is …. ?

Actual Results





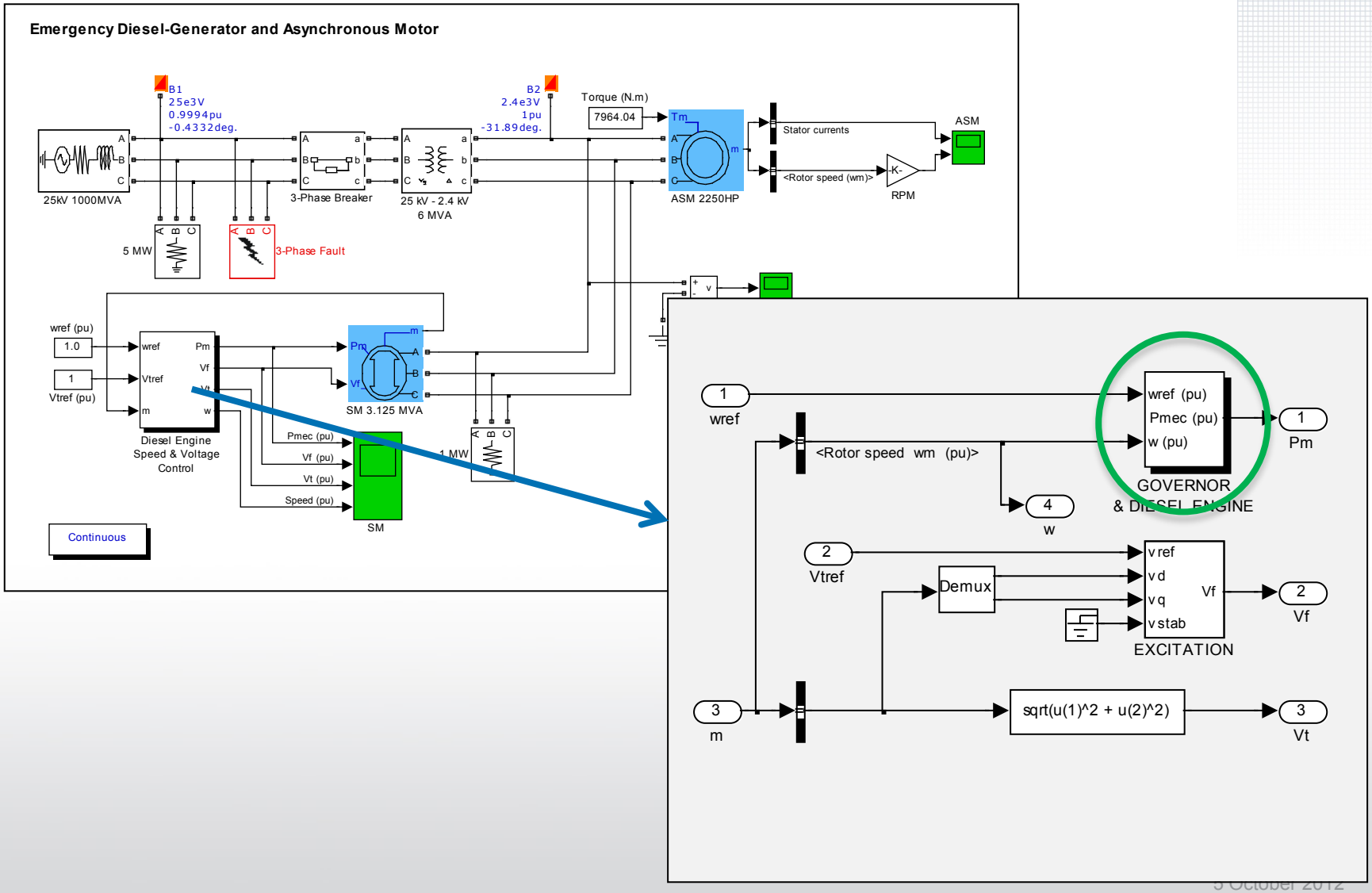
Is Dan Nuts?


V
I
PQ
Active & Reactive Power
Function Block Parameters: Active & Reactive Power
Active Reactive Power (mask) (link)
Measure the active and reactive powers of a voltage-current pair.
Parameters
Fundamental frequency (Hz):
60
OK
Cancel
Help
Apply
1
V
Mag
Fourier
Phase
Fundamental
2
I
Mag
Fourier
Phase
Fundamental
×
+
−
-K-
Deg->Rad
cos
sin
×
×
1/2
Gain
1
PQ

The “infinite bus” and “fixed frequency” mindset pervades tools

Example 3: Prime Mover Models

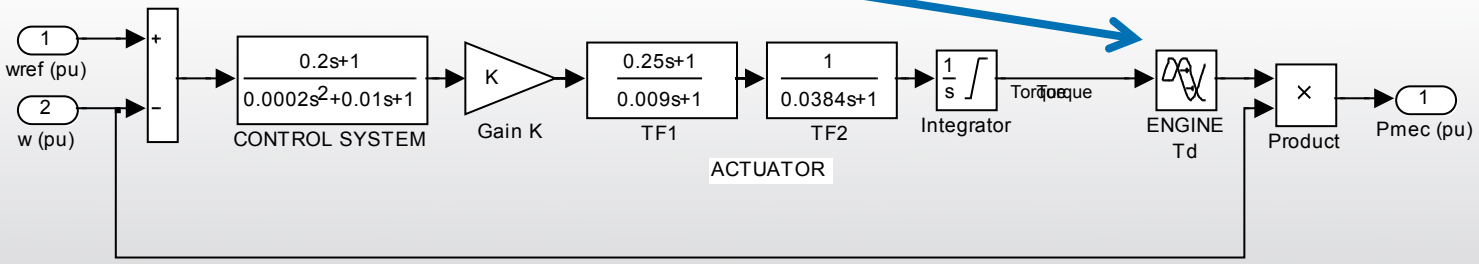
Classic Prime Mover Model



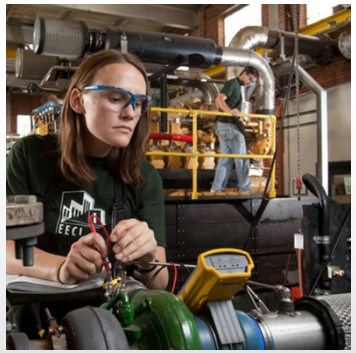
Call me a Skeptic … but …

- The Real Thing

- The Model



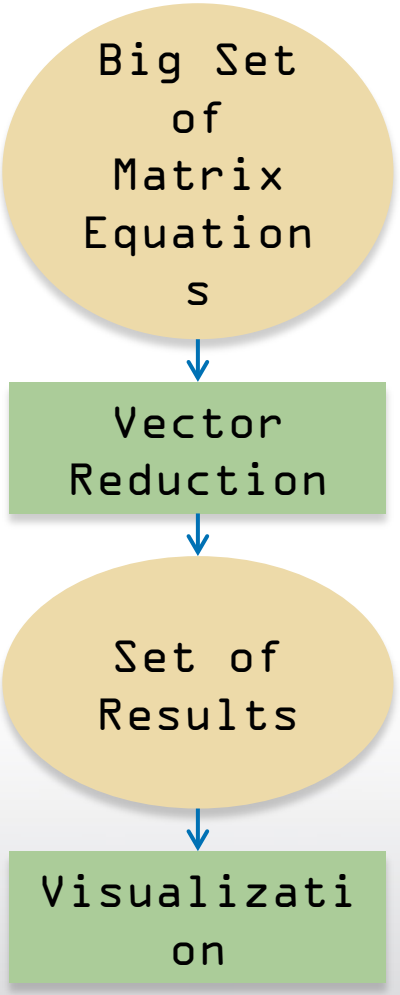
Computational Questions



Computational Questions

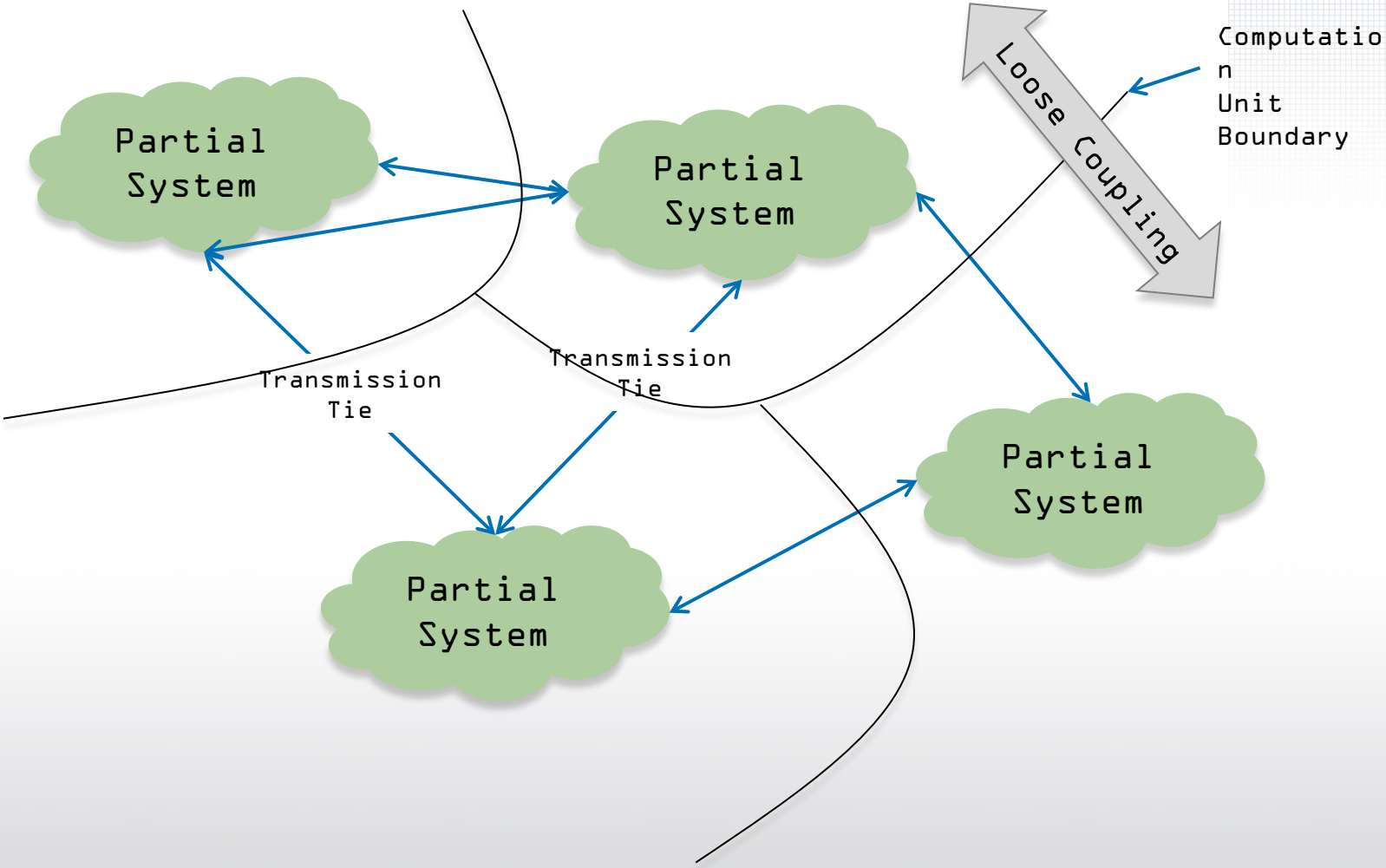
1. How can µGrid analysis exploit HPC computational capabilities?
2. What mechanisms are required to validate load, machine and prime mover models?
3. The nasty controls question: How do proprietary controls with custom settings impact analysis & performance?
4. Can computational horsepower automate µGrid planning, design and operation?
5. What is the role of visualization in µGrids?

Computationally Speaking …



Bang-up Match for vector processors
… not so good for cluster servers

Current Cluster Approach



The “Catch” with Many Smart Grid Models

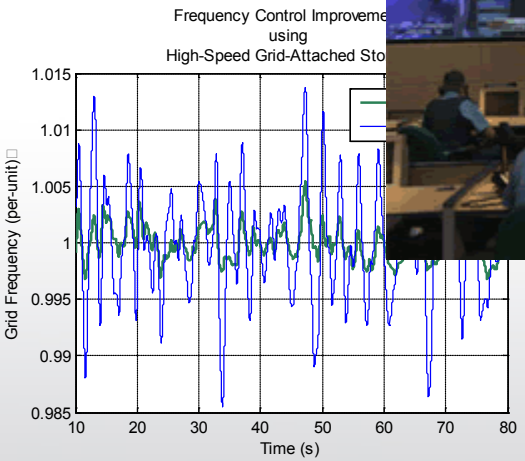
- Significant Computation Challenge on Tightly Coupled Sub-Systems

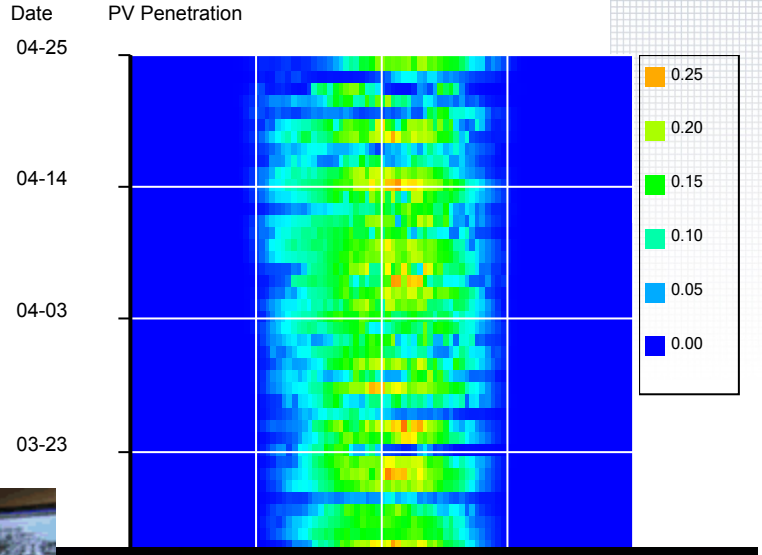
- “Loose Coupling” Techniques Introduce Artificial Behaviors

- “Tight Coupling” Bogs Down Cluster Computation

- Computation Challenges Exactly When Computation *Requirements* Increasing

Visualization





Photos From: Ben Kroposiki, NREL; Bill Kramer, NREL, m-me

Thank You

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